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Digital Factory Transformation from a Servitization Perspective: Fields of Action for Developing Internal Smart Services

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Abstract: In recent years, a complex set of dynamic developments driven by both the economy and the emergence of digital technologies has put pressure on manufacturing companies to adapt. The concept of servitization, i.e., the shift from a product-centric to a service-centric value creation logic, can help manufacturing companies stabilize their business in such volatile times. Existing academic literature investigates the potential and challenges of servitization and the associated development of data-based services, so-called smart services, with a view to external market performance. However, with the increasing use of digital technologies in manufacturing and the development of internal smart services based on them, we argue that the existing insights on external servitization are also of interest for internal transformation. In this paper, we identify key findings from service literature, apply them to digital factory transformation, and structure them into six fields of action along the dimensions of people, technology, and organization. As a result, recommendations for designing digital factory transformation in manufacturing companies are derived from the perspective of servitization and developing internal smart services.

Keywords: servitization; digital factory transformation; smart services; IoT; AI; internal services

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1. Introduction

In recent years, the manufacturing sector is facing profound changes [1]. In addition to the changes posed by technological advances themselves, primarily by digitalization, there are several other challenges for the manufacturing industry to overcome [2]. These difficulties could be an effect of the digital transformation itself. Still, they could also be the outcome of regulation or recent international events that are fundamentally altering the market situation. This applies, in particular, to manufacturing companies' production and logistics areas as their effectiveness and efficiency are crucial when they want to remain competitive, even if the production plants are located in high-wage countries, such as Germany. Selected challenges that can be observed in different companies and sectors are listed below:

- **Difficulties with international supply chains**: Recently, partly due to the COVID-19 pandemic, global supply chains have faltered. As a consequence, for example, a seamless supply of spare parts and components is not always guaranteed. This has disrupted even particularly well-optimized JIT and JIS production processes. Sourcing and supply chain issues dominate the planning and management of manufacturing processes, making it difficult to fully assemble products and requiring improvisation, as well as ad hoc decision-making. Supply constraints in some industrial sectors have become so severe that they call into question the flexible mass production's prior achievements [3]. Energy supply and price have recently forced companies to adjust their manufacturing processes. Overall, this will lead to a re-evaluation of their supply chain strategies [4].

- **Sustainability**: Sustainability is a challenge with several origins, such as the need to stay cost competitive while energy costs are increasing. Additionally, there is an increasing focus of the customers on the impact of their own consumption. The most obvious and most controversially discussed cause are regulations, for example, the European Green Deal or the restriction of internal combustion engine vehicles. As a result, the manufacturing industry has to rethink the whole life cycle of its products, starting from the design to how they are produced or even their whole business models [5,6].
- **New global players:** In addition to the growing international pressure of existing competitors and the advance of new technologies, new companies are increasingly entering the markets, putting pressure on established manufacturers. These companies do not have a production history stretching back decades but instead, build their manufacturing processes closely based on procedures and processes previously only known to the digital economy. The most prominent example is Tesla, which is focusing everything on software and digitalization and whose manufacturing plants are literally being built as greenfield projects [7].
- **Digitalization of brown-field factories:** Although traditional companies have advantages due to decades of experience, efficient product design, and deep knowledge of production processes, they must face challenges originating in the organic growth of factory layouts, processes, and technology. Most notably, this organic growth also took place in IT systems and led to a fast number of different systems that are not well-connected, hard to maintain, and difficult to replace. This brown-field burden prevents companies from benefiting easily from adopting and scaling new technological advances and, therefore, they are not able to react flexibly to changing conditions [8].
- **Skilled labor shortage:** In recent years, the labor market in industrialized countries is favoring the employee's side. In addition to the rapidly expanded demand for specialized skills in IT and engineering, the obvious factor is the ever-increasing age of the average worker. This leads to a competitive environment where, in addition to the financial incentives, the working conditions in the form of work–life balance play an increasingly more prominent role [9]. These changes will have the added benefit that older workers can extend their working life [10]. The downside is that, especially in manufacturing, predominant shift models adapting to more flexible working conditions is difficult.

Even though some generally recognizable challenges have been listed here, the actual set of barriers is always multi-faceted and can vary depending on the particular company. This is accompanied by major economic risks, but these challenges also point to significant opportunities. These include creating intelligent and adaptive production structures that make it possible to manufacture high-quality products in series under competitive conditions, even under massive uncertainty. However, this will only be possible if production processes are fully digitized, from capacity and demand planning to delivery. The associated change process can also be described as digital transformation [9]. Therefore, the ability to implement digital transformation will be a key factor for the future competitiveness of companies and for overcoming the challenges described above. In the context of industrial manufacturing, this fundamental change can also be referred to as digital factory transformation.

The increasing use of digital technologies, such as artificial intelligence (AI) and the Internet of Things (IoT), is accompanied by high investment costs. In order to be able to amortize these, it is necessary to develop services that use digital technologies and the resulting data for concrete added value, such as automated and flexible production steps [10]. The resulting increase in the importance of services and a service-oriented value creation logic in manufacturing companies is discussed under the term servitization. In recent years, scientific research has produced a wide range of findings on the concept of servitization but is particularly concerned with the question of how products can be enriched with services and marketed to external customers in service-oriented business models [11]. It has been shown, for example, that companies can increase their resilience and flexibility in turbulent times by switching from a product-oriented to a service-oriented business model [12].

Against the backdrop of the challenges and need for change outlined above, as well as the availability of digital technologies, the importance of developing internal services for manufacturing companies is increasing. We argue that the approach of servitization and its dimensions are worth transferring to production and other internal processes. In our paper, we, therefore, want to explore how existing insights from the servitization literature and a service-specific perspective can be applied to key action areas of digital factory transformation and provide a new impetus.

2. Servitization and the Development of Internal Smart Services

2.1. Digital Servitization: The Changing Character of Value Creation

Changes in industrial value creation structures have been observed at the global level, increasing the importance of services in the industrial sector, not only in an end customers' context but also between partners of an industrial value chain [13,14]. With the ongoing digitalization, seizing data-related opportunities gains significance [15]. As a result of technological developments, the increasing relevance of value co-creation and customer centricity can be observed in the manufacturing environment [16]. Research shows that the implementation of data-driven services in a manufacturing environment can provide opportunities for a firm's long-term competitive advantage [15]. Industrial firms that consequently seize the existing opportunities for digitally enabled service growth could be more resilient to global crises [12]. Moreover, following a structured servitization strategy can improve a firm's internationalization and increase its competitiveness [17]. Improving the quality of internal services can result in higher external customer satisfaction [18] and improvement in financial performance [19]. Most of the work to date has a focus on external offerings when considering servitization in the context of digital transformation. We argue that due to the increasing use of digital technologies and the changing demands on processes and employees, the approach of servitization and its dimensions are worth transferring to internal production processes.

Taking the path of servitization in a traditional, product-driven industry comes with various business opportunities but also poses several challenges. To unveil the manifold potentials of digital servitization, firms need to undertake a series of transformational steps, including processual, organizational, and ecosystem changes [15,20]. Companies that want to achieve digital servitization are faced with a variety of tension within the organizational boundaries inherent in their business relationships, including performance priorities, organizational identity, and data utilization [20]. Other challenges include inappropriate culture, a lack of customer focus and resources, and poor processes [21]. Digital servitization also demands a change in business logic. To become digital, a firm must adjust its organizational identity and culture [15]. To develop resilient businesses, it is crucial to build service-led strategies and design product-service offerings while maintaining the existing expertise in the engineering domain [12]. At the center of digital servitization stands the development of data-based services that create added value and allow new business models. The following section, therefore, describes the special features and characteristics of so-called smart services.

2.2. Characterization of Smart Services

Being researched in several domains (e.g., marketing, management, and information systems) and from different perspectives (e.g., customer perspective, company perspective), the phenomenon of smart services emerges from the fields of service science and service engineering [22]. In general, smart services can be defined as data-based, individually configurable bundles of intelligent products, digital services, or personally delivered services that are organized and performed via integrated service platforms [23]. One technological core component of smart services is the IoT. Data collected by sensors is combined with other data on digital platforms and analyzed to gain insights into the condition, use, or application-specific environment of networked physical objects. Based on these insights, digital and personally delivered service modules are combined and adapted to situational needs in a specific context. In addition, machine learning methods represent the second core technological component of smart services [24]. Trained with appropriate data, machine learning processes are able to independently perform tasks described in advance without having to reprogram each step. Smart services are, therefore, characterized by their ability to deliver individualized value propositions in a highly automated and scalable manner [25]. In addition to these special characteristics, which result from their "smartness", smart services also have traditional characteristics of services that distinguish them from physical products. To understand the shift in the offerings' nature during servitization, the following three dimensions can be considered [26]:

- First, services exhibit a high degree of immateriality, which means they are also represented by intangible elements. This can refer, on the one hand, to the resources used by the provider and, on the other hand, to the service outcome, for example, in the form of generated knowledge or customer experiences. Looking at smart services, data as a core characterizing element that is of an immaterial nature in the first place enables interaction between different actors, setting the fundament for value co-creation activities.
- The second dimension, "interactivity", describes the integration of the customer and its resources into the value-creation process, in which an intensive exchange of resources occurs between the supplier and the customer. This can mean either the exchange of data, ideas, and information or the integration of physical resources of the customer (e.g., a physical machine component) that is processed by the supplier.
- The third dimension addresses the degree of individualization, i.e., the adaptation of service offerings to the needs of the customer in a specific situation. In the context of smart services, individualization is based on the availability of data on individual actors or individual activities. Allowing a case-by-case distinction, the execution of a service can be adapted to its specific requirements in each case.

Along the dimensions, different value propositions can be classified and characterized according to the degree of proficiency. While simple physical products have a low proficiency in the three dimensions, it is relatively high for many service offerings. Against the background of the three dimensions, it is clear that successful internal servitization requires the development and management of capabilities for dealing with immateriality, interactivity and individualization, as well as a high degree of automation and scalability. This holds true, in particular, for the development of internal smart services. In the following section, an example of such a service is provided, in order to make the features easier to grasp.

2.3. AI-Based Quality Control as an Example of an Internal Smart Service

As already described, digitalization is an essential driver for service transformation in the industry. AI technologies are particularly highlighted here, as they contribute to optimizing production processes and factories in a wide range of areas. Industrial AI has the potential to improve productivity and quality throughout the entire value stream, as it can help manufacturing companies improve efficiency, reduce errors, and optimize processes [27]. The application for industrial AI-based solutions can be found, for example, in the maintenance of systems, capacity control, and internal quality assurance [28]. Industrial AI-based solutions may initially seem like completely automated IT systems, but they have a stronger service component than one might initially think. The three core characteristics of services, (1) immateriality, (2) interactivity, and (3) individualization, are also reflected in AI applications in the industrial environment. From a service-specific perspective, AI-enabled services can be understood as intelligent and, thus, "smart" digital service products [29,30]. This can be due to their varied application potential views as an archetype of smart services.

A particularly instructive example of a smart service using industrial AI is image recognition (industrial computer vision) for quality assurance. This is one of the key areas where industrial computer vision (ICV) is used to ensure that products meet the required quality standards. ICV systems typically consist of a camera or multiple cameras that capture images or videos of the product or process, software algorithms that analyze the images or videos, and a user interface that displays the results of the analysis. Algorithms can be trained using machine learning techniques to recognize specific features and defects in images or videos. For example, sheet metal components for machine housings or car bodies can be inspected for damage, such as cracks. ICV applications are not merely technical products but can be understood as smart services. This becomes clear once the three characteristics of services are considered in the context of the development and use of ICV. A key component of an ICV application is the output delivered through software algorithms that analyze images or videos of products, which are then interpreted by humans. These outputs are intangible and cannot be physically touched or experienced. This means that the value of an ICV solution is not in the physical product but rather in the insights and information provided by the computer vision system. Therefore, they can be considered immaterial.

Furthermore, ICV solutions are characterized by interactivity, as their value only arises in the collaboration between the ICV system and the user. The ICV system can detect potential damage and flag it to alert employees to a possible defect. They can then make informed decisions about whether to reject or refinish a product based on the information provided by the system. In addition, ICV-based services are individual because they can train and evolve on their own. Thus, they adapt to the specific needs of a particular manufacturing department in an application context and meet their unique requirements and processes. Thus, if the input changes permanently, this leads to different output results. Second, system decisions are dependent on environmental factors. For example, in image recognition systems, minimal changes in hardware setup or the environment of the system (light, dust, etc.) can affect the results.

If AI-based smart services are provided internally, for example, by the IT department, they are referred to as internal smart services. To successfully shape the digital service transformation in companies internally, it is essential to adopt a service-oriented perspective in the development, implementation, and roll-out of industrial AI-based applications. This service-oriented understanding is leading to changes in how business units within a company work together and between partner companies in ecosystems. However, the fact that AI services are frequently delivered through digital platforms, cloud frameworks, and edge computing capabilities also results in structural adjustments within an organization. Against the background of the three dimensions, successful servitization requires, in particular, the development and management of capabilities for dealing with immateriality, interactivity, and individualization.

3. Taking a Service Perspective on Digital Factory Transformation

The development of internal smart services is increasingly important in digital factory transformation to generate added value from data. Against this background, digital factory transformation in manufacturing can also be understood as internal servitization. By digitally linking all manufacturing processes in conjunction with data-driven service products, the production process itself is organized as a service system. Production sites develop, productize, and market their own manufacturing know-how in the form of internal smart services and thus create added value for upstream and downstream areas, other company sites, or even external cooperation partners who obtain and use these digital service products. It is important to take a holistic view of the service system in order to move from a local optimum for individual services to a global optimum for the entire production. A concerted strategy and management of intra-factory services is thus essential.

To provide new insights, we look at fields for digital factory transformation from a service perspective. Therefore, the framework of socio-technical systems is adopted, which is well-established when it comes to the analysis of production systems [31]. The framework distinguishes three levels of consideration: *people*, *technology*, and *organization*.

It is widely accepted that *people* play a decisive role in technological change processes. Technologies are used by people, and people work together in organizations. The growing importance of digital technologies further enhances the significance of the human factor in that the technologies influence human interaction. *Technology* is the basis for new production methods and manufacturing processes. What is new is the speed at which technology is developing, which is also a consequence of the fact that digital technologies have significantly shorter development times and life cycles. On the *organizational* level, a holistic and systemic view of rules, processes, and decisions with data and data analytic systems is increasingly providing the basis for these decisions.

A systemic view implies that levels are not considered separately. It is often at interfaces and overlaps the levels that are particularly relevant as design fields arise. The following simplified analytical grid with six design fields emerges for considering digital factory transformation from the internal smart service perspective (see Figure 1). The six fields of action are described in the following sections.

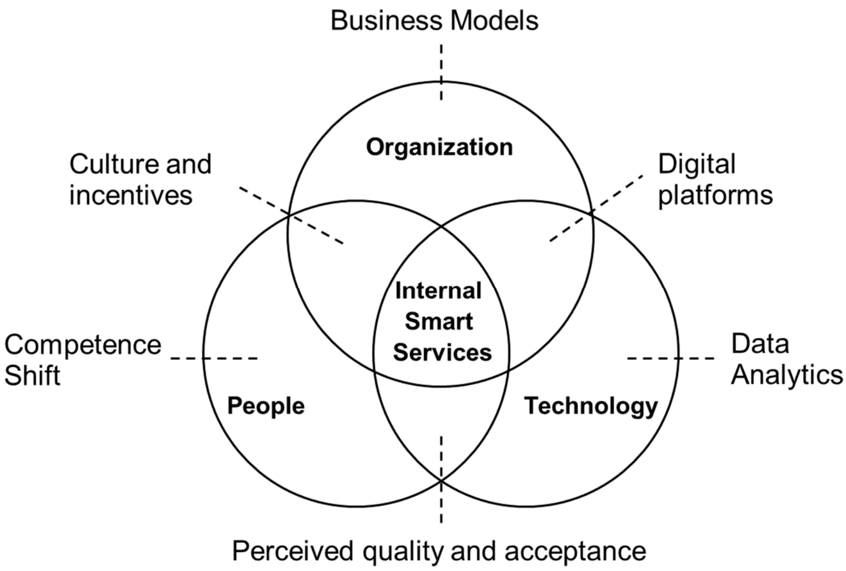

Figure 1. Fields of action for internal smart services (source: own representation).

3.1. Developing Business Models for Internal Smart Services

The development of new, service-oriented business models is at the center of the discussion about digital servitization with a perspective on external customers. The increasing use of data and the application of machine learning methods support everything-as-a-service (XaaS) business models and, in particular, use- or outcome-based revenue models in which products are not sold but rather their use or result of use are evaluated and billed on the basis of empirical data. The use of digital technologies, such as AI and the IoT, can increase the number of parameters considered, automate the evaluation of product performance, and thus create mutual transparency, which reduces the economic risk of these business models [32].

The concept of thinking and acting in business models also provides potential for manufacturing companies regarding internal value creation. On the one hand, manufacturing companies can benefit from equipment-as-a-service business models of suppliers, in which not machines and equipment parts but their usage or results are purchased. The advantages here arise from transferring risks from the factory to the equipment provider. These include, for example, the investment risk since the manufacturer assumes the financing and the costs of production, the availability risk since the supplier keeps the machine available and guarantees its performance, or even the market risk, which arises from potential fluctuations in demand and the associated low-capacity utilization [33]. Especially in times of high volatility, this can create an advantage. However, potential risk transfer is also countered by potentially negative effects. These include, in particular, the necessary sharing of data from the production process with equipment providers, the outflow of production-relevant knowledge, and the associated dependence on external suppliers. Therefore, from the factory operator's point of view, it is essential to identify the non-critical process steps and to critically reflect on the advantages and disadvantages of such business models for each case and production step individually. On the other hand, considering business models and especially evaluating profitability also plays a central role in developing internal smart services. Establishing digital infrastructures for collecting and using data must be translated into added value for the company via these services, which, at best, can be expressed in monetary terms.

However, assessing the economic benefits of smart services is not always easy. For one thing, the costs of acquiring data of appropriate quality and the resulting benefits are difficult to estimate before implementing and training appropriate algorithms. In addition, many digital technologies have marginal costs close to zero due to their scalability, which makes a precise cost analysis at the level of individual services in the production process even more difficult. On the other hand, the result is also not always easy to evaluate in monetary terms. It is easy, for example, in the case of quantifiable targets, such as productivity gains or energy savings, which are measured using the data. In other cases, the outcome is less easily quantifiable, such as generating new insights or increasing process transparency, the value of which depends on the recipient and the application context. Here, indirect benefit measurements, such as conjoint analysis, can help to supplement a purely cost-driven view with indirectly unfolding potential benefits. A problem that often exists is that the necessary data for developing smart services is collected at one point in the supply chain, but the added value from the data unfolds at another point in the process, or one department focuses on maximizing its own value from the service instead of considering its effects on the whole service system. One answer to this challenge could be the collaborative business and operating model development methodology presented in the service literature. Based on a common value proposition (e.g., saving resources by a certain percentage), the various players can jointly classify their expenditures for this and the revenues from it and develop rules and compensation mechanisms.

In order to monetize data through additional revenues, in addition to cost savings, the developed services can also be offered to other production sites within the company or even to external partners or competitors with similar production processes. The advantage of innovative companies is that they collect data early on and train algorithms and analysis models that are needed to offer smart services. For other production sites or external companies, the question later arises as to whether they want to carry out this effort themselves or use the existing "as-a-service" offerings. The development of innovative internal smart services and suitable business models thus contains the potential to soften the image of production sites as pure cost centers and generate independent revenues.

3.2. Digital Platforms and Data Ecosystems

One of the central value propositions of smart products and services lies in the acquisition, merging, and automated evaluation of different data streams with the aim of being able to offer situational and customer-specific solutions and thus increase the value of the services [34]. In this context, the potential for innovation in developing smart services also increases with the number and variety of available data sources, as the corresponding application context can be mapped more completely by the data. The inclusion of data across domains and departments, therefore, opens up new value-creation potential through services in production. In addition to data from a single production step, data from upstream and downstream process steps, from the physical environment of a machine, or even external data outside the factory (e.g., logistics or incoming orders) can be included. The aim is to break down data silos and use the available data for a wide range of internal smart services.

The technical core for this is provided by software-defined platforms, in which the data collected in various networked physical objects can be stored, merged, and combined with other data [35]. To promote the breaking down of data silos between departments, domains, and production plants, central storage forms that simultaneously enable individual data use for the development of smart services are gaining importance. An exemplary concept is represented by "data lakes", in which raw data is stored and only analyzed when required [36]. In addition to storing, various steps of data pre-processing and data preparation are needed before data can be analyzed. For example, data must be converted into suitable formats, and attention must be paid to data quality management at this point to feed the AI later with valid and meaningful data.

In addition to the technical core, the ecosystem of participating actors is also an integral part of the platform concept, which is responsible for supplying the data. Applying platformization principles on an organizational level, coordinating, and interacting across several organizational entities (e.g., departments), platform-based technical infrastructure can ease the flow of information and data. In order to promote the exchange of data across domains and company divisions, specific governance has to be established, including organizational aspects such as rules, structures, and access rights of platform value creation. As an example, clearly defined processes and steps for the collection and classification of data can be mentioned to ensure the highest possible data quality. The potential gains are to be shared between the actors, as suggested in the collaborative development of a business model in Section 3.2.

3.3. Data Analytics

The development of successful smart services fundamentally depends on the ability to collect relevant data and generate added value from it. In addition to data collection, cleansing, and merging, the key capability for developing and delivering value-adding smart services lies in applying intelligent analytics [37].

In order to develop and deliver value-adding smart services, data needs to be gradually transformed from raw data into insights and knowledge by applying analytical measures [38]. Using appropriate analytical methods, information and recommendations can be obtained from raw data to derive actions or recommendations. This process is often referred to as an information value chain or the data, information, knowledge, and wisdom (DIKW) hierarchy [39]. Raw data, which connote the properties of objects, events, and their environment as simple signs, signals, and symbols, form the basis. Combining and extending the data with meta-data requires meaning and becomes structured information [40]. If the information is put into context by incorporating experience, skills, and knowledge, knowledge is created from which decisions for action can be derived. At the top level of the information hierarchy, wisdom emerges. Here, in addition to a comprehensive understanding of the relationship between knowledge elements, ethical and aesthetic aspects are also taken into account, which can lead to an increase in the attractiveness and effectiveness of smart services [41]. Wisdom in this context can also be understood as the system's judgment to provide actions and decisions not only efficiently but also taking into account collective and individual values. Only in this way can users perceive this information as appropriate and beneficial. In general, however, actions and decisions that lead to the added value of smart services can already be derived from information and knowledge.

In order to prepare data for developing and delivering smart services, different methods of data analysis can be applied. Methods of descriptive data analysis allow historical data to be evaluated and condensed into manageable information [42]. Aggregated reports or cumulative visualizations clarify which events have occurred. In contrast, diagnostic analytics help determine why certain events occurred and thus support people in building knowledge and making better decisions. Predictive data analysis methods represent inductive approaches that lead to predictions about what will happen in the future based on historical data [43]. They play a central role in deriving smart actions and measures based on collected data. Methods of prescriptive data analysis go even one step further and provide recommendations about what should be performed and why [44]. Thus, they play a key role in bringing "smartness" into service offers.

Moreover, different types of analytics also make different contributions to the implementation of smart services (see Figure 2). While descriptive, diagnostic, and predictive procedures support the acting persons by providing information and knowledge, prescriptive analytics enables a level of automation in which decisions or actions can be made or triggered autonomously by information systems [45]. This increasing automation and, in some cases, even autonomization of situation-adaptive service provision represents a central feature of smart services [22]. However, predictive and prescriptive analytic techniques also have higher data quantity and quality requirements that must be met. Companies should, therefore, carefully consider which level of the DIKW hierarchy is possible with the existing data and capabilities of the company.

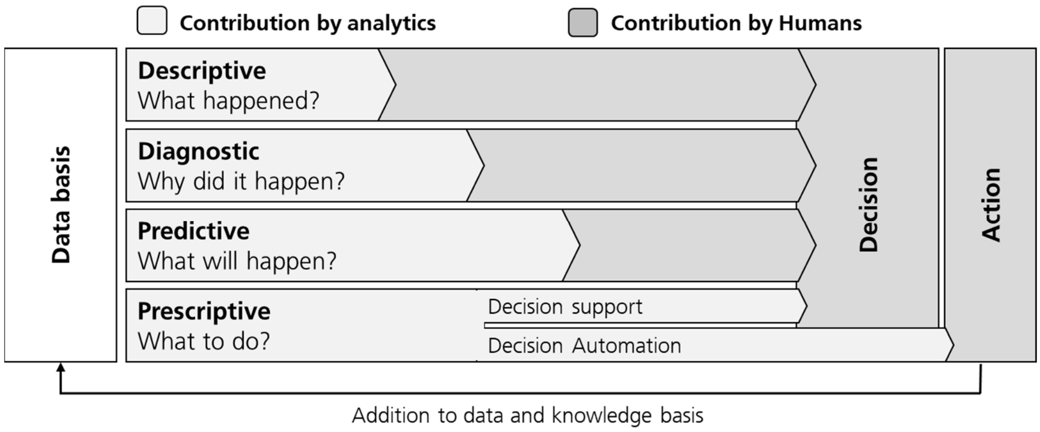

Figure 2. Contribution of analytics for implementing smart services (source: [45]).

The analysis of large volumes of data and the increasing automation of smart services is often made possible by applying technologies and methods of AI, as described in Section 2.3 [46]. Particularly in the case of smart services that use black-box artificial intelligence methods for decision-making, aspects of traceability and transparency often pose a problem. Some machine learning methods (e.g., decision trees or Bayesian classifiers) enable general traceability due to the limited number of paths, rules, and features considered. In contrast, other methods, especially deep learning algorithms (e.g., convolutional neural networks), represent a class of machine learning that prioritize predictive accuracy and, thus, the quality of results of the digital service, sacrificing (at least in part) transparency and traceability [47]. By independently linking mathematically defined entities on a multitude of layers, neural networks can increase the quality of the output, but the exact procedure remains hidden even from data specialists. Here, too, companies should critically weigh which procedures offer the best trade-off between high predictive quality and the need for assurance and acceptance among users.

3.4. Perceived Quality and Acceptance

Internal intelligent services of manufacturing companies are often used to support human work. For example, automated analysis in quality control or AI-supported production control can relieve employees of routine tasks and promote the making of good human decisions (see Figure 2). However, this implies that employees have a high level of acceptance toward the corresponding systems, and smart services are not perceived as a threat [48].

A central prerequisite for the creation of accepted smart services is the knowledge of factors influencing the perceived quality of users and their consideration during development. As a direct determinant of value-in-use and acceptance, a higher perceived quality represents a critical variable for successful smart services [49]. Many companies are currently facing challenges in this respect, as little is known about the quality requirements of smart services [50,51]. However, knowledge regarding perceived quality factors is essential, as the potential benefits are also accompanied by possible risks, such as a lack of protection for sensitive data, a loss of privacy, or the perception of surveillance [52,53]. In addition, increasing automation and the associated loss of personal relationships or the use of complex algorithms may reinforce customer-based uncertainties [25].

In order to gain high-quality perceptions and build acceptance of smart services, the involvement of stakeholders and especially users during all development phases play a central role [54]. Recurring validation cycles in different development stages, from idea generation to the marketing of smart services, can systematically address and ensure a positive perception of quality by users [55]. The so-called quality characteristics of smart services and their influencing factors can provide the basis for a structured assessment with stakeholders. Eight generic quality characteristics are known as smart services for this purpose [56]. The quality characteristics refer to the dimensions of resources and processes and results along the service provision.

With regard to the resources provided, it is apparent that a *function-supporting* role and an *aesthetic appearance* of the physical, digital, and personal artifacts are key drivers of a positive quality assessment. In addition, the capabilities of networked physical objects, digital services (e.g., functionalities), and service staff (e.g., competencies) build a basis for evaluation. Furthermore, the consideration of *security* and *privacy* represents an important quality characteristic in the design of smart services. Security addresses freedom from hazards, risks, and doubts, such as electromagnetic radiation, data access, complex solutions, or interaction with autonomously acting systems. Especially when collecting, storing, and processing personal or sensitive data, ensuring privacy also plays an important role. For example, only data directly related to the value proposition should be collected. The degree of desire for privacy is significantly influenced by the trustworthiness of technologies and acting persons.

In the process dimension, *integration quality* addresses the perception of how well and with how little effort the provided resources can be integrated into the environment and processes of a user during provision. Another characteristic is the *ease of interaction*, which refers to simple, natural, and empathetic interactions between people, technologies, and objects. In the context of smart services, for example, the factors of empathy and naturalness gain relevance in the design of a virtual agent's voice and dialog [57].

Since the value generation of a smart service depends on how well the service components adapt to the situational context of a user, *adaptability* must also be considered as a process quality characteristic [58]. High adaptability is characterized by the degree of flexibility, automated personalization, learning ability, and speed of adaptation. The last quality characteristic of the process dimension addresses the *perception of control*. This describes users' perception of the extent to which they can actively influence service delivery and are not controlled by data collection or automated decisions, or even monitored by sensors [59]. Key influencing factors of a positive perception of control are, for example, the transparency and traceability of service provision, the clear regulation of responsibilities between humans and machines, and the controllability and comfort of using the smart service [55].

In the outcome dimension, the perceived benefit of individual service components, as well as their interaction, is evaluated. The valuable contributions of personal interaction include, for example, the deepening of the customer relationship. In contrast, the contribution of digital services is evaluated along with the improved information situation through data visualization. Since the value proposition of smart services can take very different forms depending on the use case, only the *functional* and *additional benefits* can be distinguished in a generic consideration. The functional benefit addresses the effectiveness, i.e., a customer's effective and holistic task fulfillment or problem solution. Smart services aim to achieve both greater effectiveness through the data-based configuration of service components and to increase efficiency through the targeted use of resources. In addition to being functional, smart services can add value by satisfying emotional, epistemic, or social needs [60]. Emotional value addresses the evaluation of a user's affective state during or after service delivery. For example, through data-driven customization, smart services can satisfy hedonic needs and thus evoke joyful or playful emotions [61].

Furthermore, the use of data to derive evidence-based decisions can contribute to the emotional security of acting individuals. The collection and analysis of data can also lead to novel findings and insights. This can satisfy the epistemic curiosity of users and trigger a change in habitual processes. Another important aspect of added value is social value, which results from the recognition and respect of third parties and positively impacts the self-image and self-confidence of users. For example, the degree of technological innovation or their contribution to a more environmentally friendly solution contributes to social recognition.

The perceived quality has a significant influence on the acceptance of internal smart services in production, which is why the stated quality characteristics should be taken into account during the development of smart services. Moreover, it is highly relevant to emphasize that internal smart services and technologies are not intended to replace employees but to support them. Therefore, user-centered development and design should be of high importance.

3.5. Competence Shift

In particular, the use of the IoT and AI technologies, as well as the increasing service orientation, lead to changing competence requirements in companies [62]. Employees need more diverse competence profiles, which include digital and data-specific skills, such as the effective use of digital tools and different forms of human–machine interfaces [63]. Moreover, employees need a fundamental awareness of the roles, potentials, and limits of AI-driven smart services and knowledge of which data can be collected and converted into added value.

Changes are also occurring in the area of *methodological competencies*, which include, for example, flexible decision-making and problem-solving skills, process, and systems thinking. Innovative smart services with a high degree of complexity require methodological competencies such as the analysis of large volumes of data, the control of complex processes, and the solution of rapidly changing problems. Since internal smart services require a cross-domain and cross-departmental perspective and the integration and coordination of mutually dependent work processes, systems thinking and a distinctive service mindset are also essential areas of competence [64]. Collaborative work on smart services across departmental and domain boundaries requires distinctive *social skills*, influencing effective and efficient collaboration and communication. Since, in many cases, not all service components of a smart service are fully automated and often involve personal interactions, social competencies such as empathy, emotion, and creativity also remain important. Since core technologies, such as AI, have short innovation cycles and are rather untransparent, flexibility, tolerance of ambiguity, and reflectiveness are helpful *organizational skills* [65].

The competencies required at the organizational level are not needed at the individual level by every employee to the same depth and extent. Service literature, therefore, speaks of T-shaped competence profiles, which individual employees should possess [66,67]. Here, a distinction is made between horizontal and vertical competencies. Horizontal competencies describe the skills required to exchange information on a topic with other knowledge areas, specialist departments, or customers and thus be able to connect and engage in dialog. Vertical competencies, on the other hand, describe the in-depth, specialized expertise that is of central relevance to the performance of their activities. As job profiles demand increasing inter-disciplinarity due to the growing thinking and interacting that are involved in smart service ecosystems, interweaving the types of competencies mentioned in the previous section is becoming increasingly important, especially at the horizontal level [34].

This requires, for example, a broader understanding of AI and IoT technologies and their application, service orientation, and overall understanding of processes. Consequently, employees should have technical and service-specific knowledge and be able to translate this into smart service business models. In a dynamic environment with rapidly changing technologies and trends, they are able to move between different disciplines and systems, as well as cross boundaries between disciplines and link them [68].

3.6. Culture and Incentives

Internal smart services can help generate added value from data at different points in the manufacturing process. In principle, they can be applied wherever large amounts of data are generated. Digitization is not a process taking place solely within the organizational boundaries and processes of a company's IT department. In fact, digitization is a transformational process, taking place across all entities of a firm and, therefore, needs the support of many stakeholders (e.g., process owners, affected employees). On the one hand, making it as easy as possible to get started using digital technologies and analytics, for example, using marketable multi-sensor devices connected to low-code platforms, can help employees gain a positive experience and get excited about digital transformation. On the other hand, a successful shift toward more service-oriented value creation in manufacturing companies also depends on the extent to which a corresponding corporate culture, as well as a comprehensive service-oriented mindset, can be achieved among employees [69,70]. This corporate culture is characterized by the following three characteristics.

First of all, the increasingly relevant software elements of physical objects, which are not necessarily developed by a central IT department, require greater agility in production areas themselves [71]. This will also require an open approach to not-yet fully developed solutions, a change in thinking regarding what is possible, and quick short loops to fail and learn quickly for the next releases. In addition, a greater opening of the innovation and work culture is needed, in which internal stakeholders jointly develop new service offerings, and exchange across departmental boundaries and data silos is made possible [17]. A service mentality requires a high degree of user-centricity, where gains and losses of internal customer groups are the starting point for developing data-based services [70]. This also includes, for example, the consideration of emotional and social customer needs, which strengthen the overall experience and increase acceptance of smart services.

In order to maintain the necessary high data quality for the development and provision of smart services, appropriate monetary and non-monetary incentive systems are required, in addition to a corresponding corporate culture and the mindset of the employees. Up to now, many incentive structures in production have been oriented toward cost efficiency, which means that saving costs leads to rewards. However, collecting data and improving its quality often requires time and money, and the benefits of improved data quality may not become apparent until later or elsewhere. Here, holistic and process-oriented incentive systems are needed to overcome such conflicts of interest. Holistic incentive systems to improve data quality and data consistency along the manufacturing process are important areas of digital factory transformation.

4. Conclusions and Discussion

The increasing implementation of digital technologies is accompanied by the need for manufacturing companies to develop smart services in order to create added value from the generated data in the form of quality or productivity benefits and to outweigh necessary investments. This development has been discussed for several years under the term digital servitization with a view to external products and business models of manufacturing companies. However, the digitization of production machines and plants also requires companies to address the central mechanisms and capabilities of internal service-oriented value creation. Against this background, our paper aims to transfer findings from the servitization literature on digital factory transformation to derive impulses.

By focusing on challenges and fields of action in the development of smart services, we adopted a service-specific perspective that broadens the understanding of value creation, where added value is generated not only through industrial factor combination but also through interactive exchange processes and the mutual provision of knowledge and resources by service providers, customers, and cooperation partners [72,73]. The factory of the future is thus transforming itself into a service-oriented factory. In this understanding, the highly flexible series production of quality products forms the basis for developing internal smart services that continuously optimize the manufacturing process and, at the same time, turn the factory into an innovation center for the development and operation of data products and services. Based on the fields of action outlined above, the following recommendations can be derived:

1. For internal servitization to succeed, the smart services developed must be developed, implemented, and operated as professional service products from the outset. It is essential that companies address the question of profitability, i.e., whether smart services can be monetized directly or indirectly, how these effects can be evaluated, and how profits are shared among those involved. In addition, the professional development of smart services also offers the possibility of scaling them beyond the boundaries of the company's production plant. Companies can, for example, offer data, trained algorithms, or fully developed value-added services to other production sites or external companies in outlined XaaS business models that are known for external servitization and thus generate independent revenues. In order to reduce investment and fixed costs against the background of market fluctuations and external uncertainties, companies should also examine the possibility of using XaaS offerings of equipment suppliers themselves for less important and lower-risk production steps.
2. A service-oriented focus on internal value creation in production requires the establishment of integrated and scalable IT infrastructure that supports a high level of data continuity across new and existing systems. In addition, the added value of the individual smart services, as well as the whole service and production system, can be better and more holistically captured by data. The focus should, therefore, be on breaking down and merging internal data silos. This requires digital platforms in the technical sense, but also appropriate data governance and processes in the company that strengthen the sharing of data, and the creation of consistently high data quality is an important component of all departments. In addition, compensation mechanisms for contributions to high data quality should be created and incentive mechanisms for the efficient use of IT infrastructures should be developed to prevent limited resources from not being used efficiently and being threatened by overuse (tragedy of the commons) [74].
3. For shifting toward service-oriented value creation and developing internal smart services, building up suitable technical capabilities for analyzing and processing data into insights and recommendations is necessary. Companies should consider the opportunities and risks of descriptive, diagnostic, predictive, and prescriptive analytics. Early consideration in the light of available data, in-house capabilities, and the need for certainty and transparency can help set realistic goals for service development. Particularly in the production environment, where errors can have critical consequences, companies should take appropriate measures to safeguard the use of prescriptive processes in AI-based smart services.
4. To ensure that the increasing number of smart services within the production site is accepted by the workforce, users of the applications should be regarded as internal customers from the outset and involved during development, testing, and continuous optimization. This also includes focusing on the subjective perception of quality instead of objective quality. In the context of data-intensive, automated, and adaptive services, new quality characteristics must be considered during development, considering smart services' unique character to ensure acceptance.

5. To enable active engagement in service-oriented value creation for many departments in production, additional competencies are needed in the workforce. Following the concept of T-shaped competency profiles, horizontal competencies should be created that promote collaboration across divisional and departmental boundaries, problem-solving thinking, and a basic understanding of data and digital technologies, as well as services. Vertical, in-depth knowledge of the application domains should not be neglected.
6. In addition, the internal service transformation also requires an adjustment of the corporate culture and corresponding incentive systems. This includes, for example, an open approach to errors that is often untypical for manufacturing and the use of data products and services that are not fully developed. Establishing a close and solution-oriented collaboration between departments, a high level of agility in software development processes in various departments, and a constant ability to innovate and adapt are central pillars of an internal service culture. This should be flanked by holistic and process-oriented incentive and motivation systems so that all employees continuously contribute to optimizing data quality and smart service quality along the manufacturing process.

In our paper, we presented selected central findings from the servitization literature and applied them to in-plant applications in manufacturing. Due to the diversity of the topic, our paper does not claim to be exhaustive of the relevant topics and should, therefore, be understood as a first impulse. For example, one important topic is the design of data-based services for the implementation of dynamic manufacturing processes, which are controlled automatically by data and AI applications [75]. We were also unable to consider the process of internal services transformation, i.e., which steps need to be taken in which order and with what intensity. Future research should take up these central questions and empirically investigate the impulses mentioned here in the six fields of action. Finally, it should be noted that the findings and recommendations presented here cannot be applied to all companies in the manufacturing sector to the same extent. Nevertheless, it is hoped that looking at the digital transformation of the factory from a service perspective will provide new insights and support successful implementation for as many companies as possible.

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